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DESIGN AND ANALYSIS OF TRANSMISSION TOWER

MILIND KHOTKAR, ASHWATH GHODKE, NILESH SAWATE, AJINKYA THOMBRE, PALLAVI ALTE

HEAD, MEMBER, MEMBER, MEMBER, PROF.,

P.E.S. ENGINEERING,AURANGABAD

ABSTRACT

The four legged lattice towers are most commonly used as transmission line towers. Three legged towers only used as telecommunication, microwaves, radio and guyed towers but not used in power sectors as transmission line towers. In this study an attempt is made that the three legged towers are designed as 220 KV double circuit transmission line tower. The present work describes the analysis and design of two self-supporting 220 KV steel transmission line towers via three legged and four legged models using common parameters such as constant height, bracing system, with an angle sections system are carried out. In this study constant loading parameters including wind forces as per IS: 802 (1995) are taken into account. After analysis, the comparative study is presented with respective to slenderness effect, critical sections, forces and deflections of both three legged and four legged towers. A saving in steel weight up to 21.2% resulted when a three legged tower is compared with a four legged type.

In transmission line towers, the tower legs are usually set in concrete which generally provides good protection to the steel. However defects and cracks in the concrete can allow water and salts to penetrate with subsequent corrosion and weakening of the leg. When ferrous materials oxidized to ferrous oxide (corrosion) its volume is obviously more than original ferrous material hence the chimney concrete will undergo strain resulting in formation of cracks. The cracks open, draining the water in to chimney concrete enhancing the corrosion process resulting finally in spelling of chimney concrete. This form of corrosion of stub angle just above the muffing or within the muffing is very common in saline areas. If this is not attended at proper time, the tower may collapse under abnormal climatic conditions. Maintenance and refurbishment of in-service electric power transmission lines require accurate knowledge of components condition in order to develop cost effective programs to extend their useful life. Degradation of foundation concrete can be best assessed by excavation. This is the most rigorous method since it allows determination of the extent and type of corrosion attack, including possible involvement of microbial induced corrosion. In this paper, Physical, Chemical and electro chemical parameters, studied on transmission line tower stubs excavated from inland and coastal areas have been presented. A methodology for rehabilitation of transmission tower stubs has been discussed.

1 INTRODUCTION

Transmission lines are constructed to evacuate Electric Power generated in power stations over long distances across the country to substations for further transmission and distribution to various load centers.

Power transmission lines are broadly divided into two categories, viz. Alternating current (A.C.) and Direct current (D.C.) supplied in Low tension (L.T.) i.e in the range of 0.4KV to 33KV and in Extra High tension (E.H.T.) in the range of 132KV to 220KV and beyond up to 800KV. Extra High Voltage (E.H.V) is necessary to reduce power losses for transmission over long distances.

The power is carried in three phase supply through three separate conductors for each of the circuit. Hence the towers are required to be designed for single circuit, double circuit and or multi circuit as per the required technical specifications of Customers. The tower configuration and geometry depends upon the requirement of the technical specifications.

Power is transmitted through flexible metallic conductors strung at safe heights over towers. Towers are usually self-supported four legged cantilever steel structures holding the power conductors with the use of insulators at required positions on cross arms.

The power conductors are clamped to the erected towers and carried forward aerially with the use of stringing equipment avoiding

dragging of conductor on the ground.

LITERATURE REVIEW

(Analysis and Design of Transmission Tower) In this thesis, the analysis and design of a narrow-based Transmission Tower (using Multi Voltage Multi Circuit) is carried out in India, with the goal of maximizing the use of electrical supply with limited ROW and an increasing population. Transmission Line Towers contribute to 28 to 42 percent of the total cable cost. The increased demand for power is frequently handled more cost-effectively by designing various light-weight transmission tower layouts. In this project, a battle has been waged to make the cable more cost-effective while keeping in mind the goal of providing the best possible electric supply for the defined area by identifying a unique transmission tower structure. The goal of this study is to increase the current geometry by using a 220KV and 110KV Multi Voltage Multi Circuit with narrow based Self Supporting Lattice Towers. STAAD PRO v8i was used to accomplish the analysis and design.

The analysis and design of a steel lattice tower used for electricity transmission systems is done in this paper under various categories of gravity and lateral loads. The tower is analyzed under a variety of load conditions before being designed according to IS 800:1984. In order to plan the design process most correctly, proper site research data as well as environmental impact assessment data are collected prior to the design process using appropriate electronic and paper media.

During the design, relevant safety design aspects are considered, taking into account the hilly slope terrain of the location (Shimla). During the design process, non-linear imperfections in both the surroundings and the structural material are taken into account. The steel angles that were riveted together were chosen for their various purposes and load impacts. The geotechnical investigation data is used to determine the foundation details. STAAD.Pro 2008 was the software tool utilised in the process. The load calculations were performed manually; however STAAD.Pro 2008 was used to acquire the analysis and design outputs. At all times, the goal is to create the most safe design possible while keeping cost in mind.

(Design & Estimation of Electric Steel Tower) The main analysis and design of a convergent based Electrical Steel Tower utilising STAAD are presented in this study. This is done with the goal of giving the maximum amount of electric supply with the available ROW while keeping the expanding population in the area in mind. Electrical Steel tower lines cost roughly 30-48 percent of the overall cost of the lines to build.

Due to the growth in demand, lightweight constructions will be developed, which will have lower loads on the structure due to a reduction in self-weight. In examining the tower's design and estimation, the structure chosen becomes crucial. In order to make the electrical tower more cost effective than the standard ones, a small analysis was conducted. In a single electrical steel tower, the best electric supply for the needed area is also taken into account.

The construction may include 230 KV and 120 KV multi-voltage circuits, as well as self-sustaining towers that are created depending on the geometry. STAAD. Pro is used to assess and design an electric steel tower, which is also known as a steel lattice tower, for any load magnitude or orientation.

It is necessary to construct three-dimensional structures of tower members. The new edition of the code is the design of steel structures based on Indian standard code IS: 800-2007 under limit state design. The foundation design of an electric steel tower is also carried using Hansen's method in this study. In addition, a total cost estimate for the construction of an electric steel tower has been completed.

(Design and Analysis of Transmission Line Tower using Staad Pro) This research compares three types of bracings and focuses on estimating a feasible transmission line tower for various wind speeds by developing transmission line towers with hot rolled sections. 220 kV twin circuit self-supporting transmission towers with square bases are employed for this purpose. STAAD PRO is used to analyze this transmission tower, which is subjected to wind loads in Zones II, III, and IV. The load calculation for the analysis is performed in accordance with IS 802:1995. Finally, wind speed is used to compare the best transmission tower design utilizing hot-rolled steel.

(Comparative Analysis of Transmission Tower Using XX and XBX Bracing Systems in Different Wind Zones) In this work, Using STAAD Pro. V8i software, an improved steel bracing system is recommended in the construction of transmission line towers.

According to IS 802 (Part-1 / Sec-I):1995, two bracing systems, XX and XBX, are being compared in all six wind zones of India, employing seven different load circumstances. STAAD Pro V8i software is used to model and analyze the structural behavior of the tower for both bracing systems. In all wind zones of India, the XBX – bracing system was determined to be more cost-effective than the XX – bracing system.

(Multi Voltage Multi Circuit Transmission Tower Design to Reduce Right of Way) An novel strategy for reducing the ROW width in MVMCT design is proposed in this research.

When compared to traditional broad base towers, the ROW width is lowered to 40 (from 48) meters, resulting in significant cost savings when a transmission line is considered. MVMCT boosts transmission capacity as well. Within the ROW, the EMFs are also within the permitted limits. All of the stresses are within the acceptable range. When ROW is restricted, cost savings might range from 30 to 50%. As a result, MVMCT with a small basis could be a breakthrough in India, both in terms of economics and the reduction of legal concerns related to land.

Under ultimate design wind loading conditions, the load on insulator string shall not exceed 70% of its selected rating.Under everyday temperature and no wind conditions, the load on insulator string shall not exceed 25% of its selected rating.The insulators shall consist of Anti Fog Disc Insulators orlong Rod Insulators having Electro-Mechanical strength of 120 KN for Suspension Strings & 160 KN for Tension Springs and minimum creep-age of 31mm/k

2. METHODOLOGY

Transmission Tower Configuration

Reliability level	1
Wind zone	II
Terrain category	2
Return period	50 years
Basic Wind speed, Vb	39 m/s
Design wind pressure, Pd	958.69 N/m2
Ground clearance, h1	12.4
Maximum sag of the lower most conductor wires, h2	0.4 m

Vertical distance between conductor wires, h3	4 m
Vertical distance between conductor and ground wire, h4	5.2 m
Entire height of the tower	22 m
Span length	50 m
Base width of the tower, b	4 m
The geometry of the tower	Square base

Table 1. Tower Configuration

B. Design Parameters

Wind Effects [Refer IS 875 (Part 3) : 2015]

Design Wind Speed Vz = 42.12 m/s

Design Wind Pressure Pd: The design wind pressure which is distributed along the height of the towers, conductors and insulators shall be determined by the following expression:

Pz = 0.6VZ2 = 1065.2148 N/m2 ,Pd = kd ka kc pz = 958.69 N/m2

Wind Load on Tower Fwt = 7333.9785 N

Wind Load on Conductor and Ground wire Fwc = 7221.6201 N

Wind Load on Insulator Strings Fwi = 2070.7704 N

Sag Tension: Sag tension calculation for conductor and groundwire shall be made in accordance with the relevant provisions of IS 5613 (Part 2/ Sec 1): 1985 for the following combinations:

Max Sag S = WL2 /8T = (0.372 x 502)/(8 x 699) = 0.4 m

Seismic Consideration: The transmission line tower is a pin-jointed light structure comparatively flexible and free to vibrate and max. wind pressure is the chief criterion for the design. Concurrence of earthquake and max. wind condition is unlikely to take place and further seismic stresses are considerably diminished by the flexibility and freedom for vibration of the structure. This assumption is also in line with the recommendation given in cl. no. 3.2 (b) of IS: 1893-1984. Seismic considerations, therefore, for tower design are ignored and have not been discussed.

C. Staad Modeling

Limit state design is a one with both strength and serviceability is considered while designing the structure. Coming to steel structures IS 800-2007 in limit state design by using STAAD. Pro plays an important role in designing huge structures were it having a number of elements like ties and strut members.

3.BRACING SYSTEMS

Once the width of the tower at the top and also the level at which the batter should start are determined, the next step is to select the system of bracings. The following bracing systems are usually adopted for transmission line towers.

3.1 Single web system:

It comprises either diagonals and struts or all diagonals. This system is particularly used for narrow-based towers, in cross-arm girders and for portal type of towers. Except for 66 kV single circuit towers, this system has little application for wide-based towers at higher voltages.

3.2Double web or Warren system:

This system is made up of diagonal cross bracings. Shear is equally distributed between the two diagonals, one in compression and the other in tension. Both the diagonals are designed for compression and tension in order to permit reversal of externally applied shear. The diagonal braces are connected at their cross points. Since the shear preface is carried by two members and critical length is approximately half that of a corresponding single web system. This System is used for both large and small towers and can be economically adopted throughout the shaft except in the lower one or two panels, where diamond or portal system of bracings is more suitable.

3.3 Pratt system:

This system also contains diagonal cross bracings and, in addition, it has horizontal struts. These struts are subjected to compression and the shear is taken entirely by one diagonal in tension, the other diagonal acting like a redundant member.

It is often economical to use the Pratt bracings for the bottom two or three panels and Warren bracings for the rest of the tower.

Design of the members of the tower:

In X-type bracings the member which is under tension, due to lateral load acting in one direction,

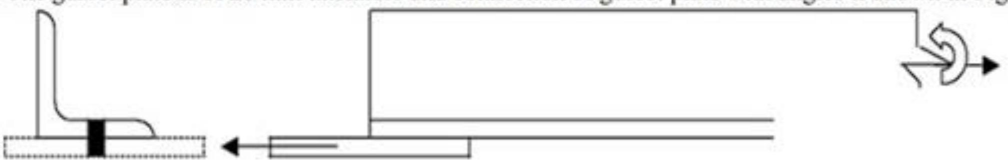
undergoes compressive force, when the direction of the lateral load is changed and vice-versa (as in the member force calculations

Hence, such members are to be designed to resist both tensile and compressive forces

The Members used in the Towers are standard Indian Angles of 1 Main leg: ISA 200 * 200 * 25 single angle back to back section.

2. Diagonal and Cross arm bracing: ISA 100 * 100 * 8 single angle 3. Horizontal bracing: ISA 130 * 130 * 10 single angle.

The gusset plate is of 20 mm thickness and connection of gusset plate with angles is shown in Figure 4.



7.1 Design of tension member by limit state method (IS 800 2007) Tension members are linear members in which axial forces act to cause elongation (stretch). Such members can sustain loads up to the ultimate load, at which stage they may fail by rupture at a critical section The design strength of the tension member shall be minimum of T dq^ * ,T de and T A a

7.1.1 Strength Due To Yielding of Gross Section

The design strength in the member under axial tension is given by:

T m - f_{i} * A_{mu} / gamma mr where

You the partial safety factor for failure in tension by yielding. The value of gamma me according to IS800 2007 is 1.10

7.1.2 Design Strength Due To Rupture of Critical Section Tension rupture of the plate at the net cross-section is given by

T L -0.9(A n / gamma min) where

the partial safety factor against ultimate tension failure by rupture (7 4 = 1.25) Single Angle Tension Member

The strength of an angle connected by one leg as governed by tearing at the net section is given by T xx -0.9f x ^ * A xx * gamma xx -[1^ xx f y] where

accounts for the end fastener restraint effect and is given by

tilde B = 1.4 - 0.076 (wit) (f, 6) (b,1), Yu, Y) 0.7 The b, (shear lag distance) is calculatedas shown in the Figure S

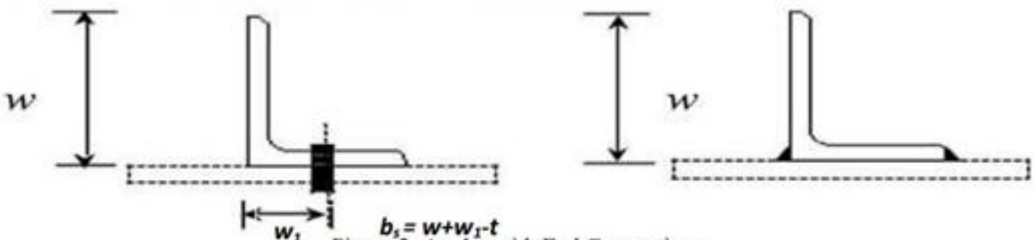


Figure 3: Angles with End Connection.

Design Strength Due To Block Shear

A tension member may fail along end connection due to block shear as shown in Figure 6. The corresponding design strength can be evaluated using the following equations. The block shear strength Tab at an end connection is taken as the smaller of Ta- (A137) 0.91,AY) or, T (0.91 A/(31) + A_1/Ym)

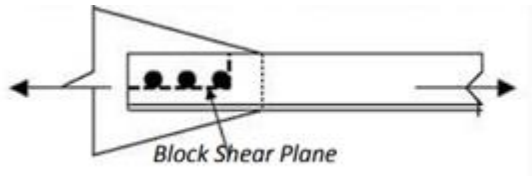


Figure 4: Block Shear Failure.

Design charts tension member

The charts have been prepared based on IS 800:2007 for Tension members. The procedure is shown below.

Assumed material properties:

fy = 250 MPa, fu = 400 MPa, fub = 410 MPa

7.2.1Design chart for Main leg ISA 200×200×25

Tensile Strength of Single Angle ISA 200 X 200 X 25 (As per IS 800:2007) with single row bolted

connection as shown in Figure 7 (9nos. 20mm dia.).

The no of bolts considered for the design of tension members for end connections is based on minimum

no. of bolts required for the full strength of the angle for Block shear.

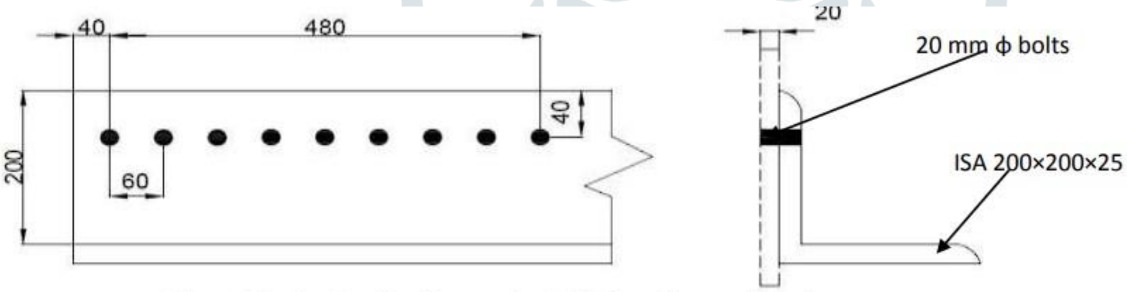


Figure 7: Design Details of leg member (All Dimensions are in mm).

Design strength due to yielding of gross section

Tdg = fy Ag/ γmo

Ag= 9380 mm2

(from steel table), γm0 = 1.1

Tdg= 250×9380/1.1 = 2131.818 kN

7.2.1.1 Design Strength due to rupture of critical section

e = 40 mm, p = 60 mm

Tdn= 0.9fu Anc /γml + βAgo fy /γm0

Anc = (200 – 22 – 25/2) ×25 = 4137.5 mm2

Ago = (200 – 25/2) ×25 = 4687.5 mm2

β = 1.4 – 0.076 (w/t) (fu/fy) (bs

/Lc) ≤ (fu γm0 / fy γm1) ≥ 0.7

Lc = 60×8 = 480, bs = 200+140-25 = 315

β = 1.4 – 0.076(200/25) (250/410) ((315)/480) = 1.156 (> 0.7)

1.156 < (fu γm0 / fy γm1) = (410×1.1)/ (250×1.25) = 1.44

Therefore, Tdn= (0.9×4137.5×410)/1.25 + (1.15×4687.5×250)/1.1 = 2446.5 kN

Design strength due to block shear

The block shear strength Tdb, at an end connection is taken as the smaller of

Tdb1 = (Avgfy /(√3γm0) + 0.9fuAtn /γm1) or, Tdb2 = (0.9fuAvn /(√3γm1) + fyAtg /γm0)

Avg = (40+60×8) ×25 = 13000 mm2

Avn = (40+60×8-22×7.5) ×25 = 8325 mm2

Atg = (60×25) = 1500 mm2

Atn = (60-0.5×22) ×25 = 1225 mm2

Tdb1 = ((13000×250)/ (√3×1.1)) + ((0.9×1225×410)/1.25) = 2067 kN

Or, Tdb2 = ((0.9×8325×410)/ (√3×1.25)) + ((1500×250)/1.1) = 1759 kN

Therefore, the block shear strength is Tdb = 1759 kN

Now, Strength of the single angle Tension member should be least of the above three values (i.e. 2131.81 kN, 2446.5 kN and 1759 kN) which is equal to 1759 kN.

As per our calculation we get that the maximum tension force is in the leg member of the ground panel which is 245.67 kN i.e. factored load = 245.67×1.5 = 368.5 kN is lesser than the above three values. Therefore our design is safe for maximum tension.

Design chart for Diagonal member ISA 100×100×8

Tensile Strength of Single Angle ISA 100 X 100 X 8 (As per IS 800:2007) with single row bolted connection as shown in Figure 8 (3nos 16mm dia.).

The no of bolts considered for the design of tension members for end connections is based on minimum no. of bolts required for the full strength of the angle for Block shear.

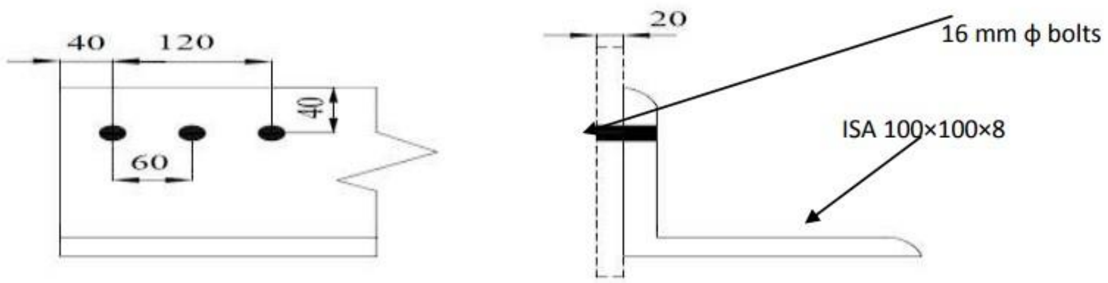


Figure 8: Design Details of diagonal member (All dimensions are in mm).

Design strength due to yielding of gross section

Tdg = fy Ag/ γmo

Ag= 1539 mm2

(from steel table), γm0 = 1.1

Tdg= 250×1539/1.1 = 349.7 kN

7.2.2.2 Design Strength due to rupture of critical section

e = 40 mm, p = 60 mm

Tdn= 0.9fu Anc /γml + βAgo fy /γm0

Anc = (100 – 18 – 8/2) ×8 = 624 mm2

Ago = (100 – 8/2) ×8 = 768 mm2

β = 1.4 – 0.076 (w/t) (fu/fy) (bs

/Lc) ≤ (fu γm0 / fy γm1) ≥ 0.7

Lc = 60×2 = 120, bs = 100+44-8 = 136

β = 1.4 – 0.076(100/8) (250/410) ((136)/480) = 0.74 (> 0.7)

0.74 < (fu γm0 / fy γm1) = (410×1.1)/ (250×1.25) = 1.44

Therefore, Tdn= (0.9×624×410)/1.25 + (0.74×768×250)/1.1 = 313 kN

Design strength due to block shear

The block shear strength Tdb, at an end connection is taken as the smaller of

Tdb1 = (Avgfy /(√3γm0) + 0.9fuAtn /γm1) or, Tdb2 = (0.9fuAvn /(√3γm1) + fyAtg /γm0)

Avg = (40+60×2) ×8 = 1280 mm2

Avn = (40+60×2-18×2.5) ×8 = 920 mm2

Atg = (40+18) ×8 = 464 mm2

Atn = (40+18-0.5×18) ×8 = 392 mm2

Tdb1 = ((1280×250)/ (√3×1.1)) + ((0.9×392×410)/1.25) = 283.6 kN

Or, Tdb2 = ((0.9×920×410)/ (√3×1.25)) + ((464×250)/1.1) = 262 kN

Therefore, the block shear strength is Tdb = 262 kN

Now, Strength of the single angle Tension member should be least of the above three values (i.e. 349.7 kN, 313kN and 262 kN) which is equal to 262 kN.

As per the calculation, the maximum tension force is obtained in the diagonal member of the sixth panel which is45.27 kN i.e. factored load = 45.27×1.5 = 67.9 kNis lesser than the above three values. Therefore the design is safe for maximum tension.

Design of compression member by limit state method (IS 800:2007)

.Design chart for Main leg ISA 200×200×25

Length = 3.02 m

K = 0.85

fy = 250 MPa

A = 9380 mm2

rmin = 60.5 mm

KL/ rmin = (0.85×3020)/60.5 = 42.43

From Table 10 of IS 800:2007, the member belongs to buckling class c.

Therefore, from Table 9(c) of IS 800:2007 the values of fcd are found using KL/r = 42.43 and fy = 250 MPa.

Here,

For, KL/r = 40 => fcd = 198 MPa

KL/r = 50 => fcd = 183 MPa

Therefore, for KL/r = 42.43

fcd = 194.35 N/mm2

Thus, strength of the angle as column

Pd = A× fcd = 9380×194.35 = 1823050 N = 1823 kN

Working load = 1823/1.5 = 1215 kN > 245.67 kN

Therefore, the section is safe for maximum compressive force

CONCLUSIONS

On the whole, this study has attempted to provide an insight into the design of foundation and staad analysis. The study yielded the following conclusions based on the laboratory experimentation carried out in these investigations.

The precise planning and better implementation of the project require the assimilation of field investigation data. The goal of this project was to demonstrate how to use the advanced structural tool STAAD.pro to solve complex engineering issues involving beams and nodes with ease and in a short amount of time. Following conclusions can be made:

A. Least weight of the tower implies greatest economy in the transmission line cost.

B. The wind force normal to cables was found to the worst of all. The design given by STAAD.pro has been found to be complying with IS-800: 1984 and all the members were safe.

C. XBX – bracing system is found to be optimum and economical in design of electrical transmission line towers in both strength and cost of material required in comparison to XX – bracing system.

After knowing the type of soil, we selected wet type of foundation.

We observed during the design process, all the design criteria's satisfied

As per is code provisions

After designing the foundation, then we are going to design seismic and wind analysis by using staad pro.

After observing cyclone, we are assign 220kmph in wind analysis.

We observed in analysis of seismic the transmission tower was stable.

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